CALIBRATION OF THE PIC ON NEWNET STATIONS

Purpose

This Meteorology and Air Quality Group (MAQ) procedure describes the calibration of the pressurized ion chambers (PICs) on NEWNET stations.

Scope

This procedure applies to the routine calibration of the PICs on NEWNET stations.

In this procedure

This procedure addresses the following major topics:

Signatures

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General information about this procedure

Attachments

This procedure has the following attachments:

Number	Attachment Title	No. of pages
1	Hazard Control Plan	1
2	Calibration Factor for NEWNET PICs	4

History of revision

This table lists the revision history and effective dates of this procedure.

Revision	Date	Description Of Changes
0	1/8/02	New document.
1	12/22/04	Quick-change revision to convert HCP to HR.

Who requires training to this procedure?

The following personnel require training before implementing this procedure:

- personnel assigned to calibrate NEWNET

Annual retraining is required and will be by self-study ("reading") training.

Personnel previously trained to revision 0 of this procedure do not require re-training to this revision.

Training method

The training method for this procedure is "**self-study**" (reading) and is documented in accordance with the procedure for training (MAQ-024).

Prerequisites

In addition to training to this procedure, the following training is also required prior to performing this procedure:

- RadWorker Training
- MAQ-011, "Logbok Use and Control"
- Hazard Review "NEWNET Instrument and Station Maintenance"
- RRES-ES-Field, "Field Safety For All Employees"
- RRES-ES-Driving, "Driving and Towing Safety For All Employees"

General information, continued

Definitions specific to this procedure

NEWNET: Neighborhood Environmental Watch Network.

PIC: Pressurized Ion Chamber.

References

The following documents are referenced in this procedure:

- MAQ-011, "Logbook Use and Control"
- MAQ-024, "Personnel Training"
- Reuter-Stokes Manual RSS-131
- Reuter-Stokes Manual RSS-1013
- RRES-ES-Field, "Field Safety For All Employees"
- RRES-ES-Driving, "Driving and Towing Safety For All Employees"

Note

Actions specified within this procedure, unless preceded with "should" or "may," are to be considered mandatory guidance (i.e., "shall").

Calibration of the PIC

Calibration frequency

As good practice and in accordance with the NEWNET QA plan, the NEWNET PICs are calibrated on an annual basis. This means the calibrations should average one per year; it does not mean that they must be done at intervals of 365 days or less.

In addition to the annual calibration, a calibration should also be performed if there is any question about the performance, or if a PIC is replaced.

Principles of PIC calibration

If possible, calibrations should be performed in the field with the PIC connected in the normal way. Thus, the calibration includes the electronics and any possible software manipulation that occurs before the data are displayed on the NEWNET website (newnet.lanl.gov).

During maintenance and when changes are made, it is good practice to measure the voltages at the data logger and at other key locations. These values should be documented in the station logbook. Standard readings of this sort are helpful when troubleshooting the system. It is also useful to record the zero reading, i.e., the reading when the PIC electronics is set to “zero”.

During a calibration, the response of the PIC will depend on:

- the type and activity of the radioactive calibration source,
- the distance from the source to the PIC, and
- the background radiation.

The calibration source must be cesium-137 (Cs-137). Corrections are made, as needed, for the activity, distance, and background. These details are discussed in the following sections.

Handling and transporting the sources

Keep each source in its dedicated storage box when not in use. Never carry the source in a pocket – keep it in its storage container except when in use. Minimize your time around the source and maximize your distance and shielding from it.

These sources are “non-accountable” and do not need to be tracked nor have a formal source custodian. It is not a requirement to keep them locked, though MAQ group policy is to keep them in a specified locked cabinet at TA-54 Cave.

Calibration of the PIC, continued

Activity of the source

The calibration depends on the activity of the source, *C*, measured in curies or microcuries. The activity of the source must be corrected for radioactive decay using the textbook formula: $C = C_0 \exp(-0.023t)$; the time t is in years and can be approximated to the nearest tenth of a year.

The two standard sources used with NEWNET were purchased from Isotope Products Lab (IPL) in August 2001. Specifications are as follows.

- Source number 812-44-1, 18.30 microcuries on 15-Aug-01.
- Source number 812-44-2, 17.71 microcuries on 15-Aug-01.

The two sources agree to better than 1%.

Accuracy

Aim for 1%. An accuracy of 5% is acceptable. The overall accuracy of the PICs depends on the energy of the gammas, as shown in the figures in the Reuter-Stokes manuals (e.g., see Figure 3 on page 11 of the RSS-131 manual and Figure 2.1 on page 4 of the RSS-1013 manual).

Distance of the source

The reading from the PIC depends on the distance and follows the inverse-square law. When the source is in its standard configuration, the effective mean distance from source to PIC is 5.7 inches. Therefore, a change in distance of 0.1 inch is significant.

The standard configuration for the source is as follows.

- Keep the source inside its half-inch-thick plastic box, with the quarter-inch-thick sponge pad between the source and the PIC.
- Orient the PIC in its standard configuration with the electronic connector underneath and the flat 12-by-12-inch surface of the PIC uppermost.
- Place the source within a quarter inch of the middle of the 12-by-12-inch surface. Note: horizontal displacement is much less critical than vertical displacement.

Calibration of the PIC, continued

Background radiation

The terrestrial and cosmic background radiation is about 5 to 8% of the source radiation, and therefore background must be measured and subtracted. The background should be measured to about 1 microR/h. This is straightforward, unless something unusual happens during the calibration. For example, a rain or snowstorm can change the background by several microR/h. In this case, the background will not be constant before and after the calibration, and the calibration will need to be repeated.

Expected reading

If the decay-corrected activity is *C* curies and the source is in the designated position described above (see "Distance of the source"), the expected reading, after subtracting background, is 13.9*C* R/h. For example, if *C* = 17.5 microcuries, the expected background-corrected reading is 243 microR/h.

Steps to calibrate the PIC

To calibrate the PIC, perform the following steps:

Step	Action
1	Arrange with the NEWNET comment coordinator to enter a comment saying when the PIC will be calibrated.
2	Select one of the IPL Cs-137 sources and calculate the decay-corrected activity, *C*, using the standard textbook formula (see "Activity of the source", above). With the source in the designated position (see "Distance of source", above) the expected increase will be 13.9*C* R/h.
3	Optional step: with the source more than 10 feet from the PIC, record and average 10 background readings from the visual display, if this is available.
4	If you know the precise timing of the datalogger interval, place the source in the designated position at least 1 minute before the beginning of the interval and leave it in place until at least 1 minute after the end of the interval. Alternatively, leave the source in place for at least 31 minutes. (See "Distance of source" for the designated position.)
5	Optional: if there is a visual display, record at least 20 visual readings after the PIC has stabilized, and record 10 more visual readings after the source is removed 10 feet away.
6	The data recorded in the computer database must show: (a) a flat background (±1 microR/h) before and after the calibration; (b) a spike during the calibration interval; (c) significant increases (>5 microR/h) during the 15 minute intervals immediately before and immediately after the calibration interval. If not, the calibration must be repeated.

Steps continued on next page.

Calibration of the PIC, continued

Step	Action
7	Calculate the background by averaging at least 10 readings from the flat regions before and after the calibration (described in step 6a).
8	Subtract the background from the spike to obtain the observed increase. (Optionally, compare this with the visual readings and discuss anomalies with the NEWNET the project leader.)
9	Compare the observed increase with the expected increase. If they disagree by more than 5%, discuss the results with project leader. If the results are unacceptable, the PIC should be replaced and sent to Reuter Stokes for repair and recalibration.
10	Coordinate with the NEWNET Comments coordinator to summarize the numerical results in the "Comments_data" table of the NEWNET database. Coordinate with the NEWNET Database Manager to enter the calibration date in the "Web_location_info" table or other table, as appropriate, if the database is updated. Additional details may be documented in newnet2.lanl.gov\newnetcommon\Calibrations.

Records resulting from this procedure

Records

The following records generated as a result of this procedure are to be completed within 1 month and are maintained in the MAQ database:

- Results are summarized in the “Comment_data” table of the NEWNET database;
- The calibration date is in the “Web_location_info” table, or other appropriate table if the database is updated.
- Additional details may be documented in Excel spreadsheets or Word documents in newnet2.lanl.gov\newnetcommon\Calibrations.

Click here to record “self-study” training to this procedure.

HAZARD REVIEW

Work tasks/Steps	**Hazards, Concerns, and Potential accidents; Likelihood/ Severity**	**Controls, Preventive Measures** *(e.g., safety equipment, administrative controls, etc.)*	**Hazard Level** *from IMP 300-00-00 Hazard Grading Matrix*
Radiation exposure from calibration source (Cs-137)	occcasional / negligible = minimal	Sources are non-accountable. Follow the time-distance-shielding principles to minimize exposure. Radiation exposure from calibration source (Cs-137) is very low energy and poses minimal risk even in long exposures. Personnel will not carry source in pockets and will minimize exposure time and maximize distance and shielding. Keep away from dosimeter badge.	Low

Wastes or residual materials resulting from process

None.

Emergency actions to take in event of control failure

For all injuries, provide first aid and see that injured person is taken to Occupational Medicine (only if immediate medical attention is not required) or the hospital. Follow all site-specific emergency plans for any radiation or explosives emergencies.

CALIBRATION FACTOR FOR NEWNET PICS

The calibration factor for the NEWNET PICs was determined from 31 PICs and compared with a calculation and with the environmental TLDs. This work was performed between 17-July-2001 and 24-October-2001 and is documented in the NEWNET database and in newnet2.lanl.gov\newnetcommon\Calibrations.

BASIC CHECKS

Zero readings were less than 0.2 microR/h.

Background readings were checked and determined to be consistent within 0.5 microR/h.

The raw voltages from the PIC were consistent to better than 0.5%.

Three Cs-137 sources were compared; results were consistent to better than 1%.

1. Source No. 2S154, manufactured by Amersham, 12.02 microcuries (+/- 3.7%) on June 1 1985, British Calibration Service certificate of calibration R2042, obtained from gamma calibration set No. 1760 owned by Jose Gutierrez, ESH-12. Decay-corrected activity in July 2001 was 8.3 microcuries.
2. Source No. 812-44-1, type D, manufactured by Isotope Products Lab., 18.30 microcuries (+/- 3.1%) on August 15, 2001, owned by MAQ. Decay corrected activity in October 2001 was 18.2 microcuries.
3. Source No. 812-44-2, type D, manufactured by Isotope Products Lab., 17.71 microcuries (+/- 3.1%) on August 15, 2001, owned by MAQ. Decay corrected activity in October 2001 was 17.6 microcuries.

Three distances were compared and scaled with $1/r^2$ to better than 1%. The distances were 5.4 inches, 5.5 inches, and 5.7 inches. (Note: the effective mean distance was obtained by integration over the volume of the PIC, and is not equal to the distance to the center of the PIC; the integral that derives the familiar result for center of gravity involves components of vectors, and is only approximate this case.)

CALIBRATION

A Cs-137 source was placed on each PICs as described in the NEWNET calibration procedure and the total response was measured, listed as “Total” in the table. With the source removed more than 10 feet from the PIC, the background was measured. The response of the PIC, listed in the table as “Source” = Total – Background.

The calibration factor, “Cal.Fac.” is the source response divided by the source activity, normalized to a distance of 5.7 inches, which corresponds to an Isotope Products Lab. Type-D source inside its 0.5-inch-thick plastic box with the sponge pad between the source and the PIC. In this configuration, the expected response of the PIC (R/h) is the calibration factor multiplied by the decay-corrected activity of the Cs-137 source (Ci).

The original data are in the Excel spreadsheets in newnetcommon\Calibrations\Fy01.

Name	ID	Total microR/h	Background microR/h	Source microR/h	Cal.Fac. R/h•Ci
Area G South	N4509	263.4	19.6	243.8	13.4
Buey	EPA26	255.0	18.0	237.0	13.0
Eastgate Synrgtcs	L3102	267.9	16.6	251.3	13.8
Kappa	M222	268.6	16.3	252.3	13.9
Met tower	M243	261.9	17.1	244.8	13.5
TA54 test		262.4	20.1	242.3	13.3
Eastgate Cmpbll		276.5	17.5	259.0	14.2
DP	EPA100	254.3	15.6	238.7	13.1
LAHS	M227B	265.8	14.2	251.6	13.8
San Ildefonso	M3356	269.6	13.3	256.3	14.1
Ohkay Ow.	M239	257.1	12.3	244.8	13.5
Santa Clara	M231	262.9	17.1	245.8	13.5
Santa Fe	M245	271.2	15.0	256.2	14.1
Espanola	M235	272.5	13.2	259.3	14.2
S-site	M224	277.1	15.1	262.0	14.4
RSS131-920	920	273.5	13.7	259.8	14.3
RSS131-921	921	274.6	13.7	260.9	14.3
RSS131-922	922	264.5	13.7	250.8	13.8
RSS131-923	923	271.6	13.75	257.9	14.2
RSS131-924	924	269.1	13.8	255.3	14.0
706849	706849	138.4	12.7	125.7	13.6
187339	187339	140.7	12.6	128.1	13.9
M-252	M-252	142.3	12.6	129.7	14.0
195599	195599	145.9	13.4	132.5	14.3
M-3357	M-3357	143.0	12.6	130.4	14.1
187340	187340	145.3	13.4	131.9	14.3
184514	184514	143.3	12.9	130.4	14.1
M-248	M-248	145.4	12.2	133.2	14.4
RS-6-2217	RS-6-2217	139.7	13.5	126.2	13.6
gloss white	gloss white	141.3	13.1	128.2	13.9
RSS131-879	879	147.9	13.5	134.4	14.3

The mean calibration factor for a type-D Cs-137 source in its box with the sponge pad underneath is **13.9 R/h•Ci**. For a type-D Cs-137 source removed from its box and placed directly on the PIC the calibration factor must be scaled by the inverse-square law: 13.9(5.7/5.5)2 = **14.9 R/h•Ci**.

The standard deviation of all 31 measurements in the table is 2.8%, which is better than the expected accuracy of 5%.

Twenty-five of the PICs in the table were calibrated at the Nevada Test Site, whereas the six RSS-131 PICs were calibrated by Reuter Stokes using their calibration procedure RS-SOP-238.1. The average calibration factor for the six RSS-131s is 14.1 R/h•Ci, which is in good agreement with the overall average of 13.9 R/h•Ci..

CALCULATION

According to "The Health Physics and Radiological Health Handbook" (1992) page 53 and "Problems and Solutions in Radiation Protection" by James Turner (1992) page 42, the standard rule of thumb $X=6CE/r^2$ is 4% low for Cs-137. X is in roentgen/hour, C in curies, r is in feet, and E = 0.662*0.85 MeV for Cs-137. Therefore, at r = 5.7 inches, the calibration factor, $R/C = 1.04*6*0.662*0.85(12/5.7)^2$ = 15.6 R/h•Ci.

About 10% of the gammas are abosorbed in the 1/8-inch-thick steel wall of the PIC and in the other materials between the source and the argon. (According to the NIST web site http://physics.nist.gov/PhysRefData/XrayMassCoef/cover.html the mass absorption coefficient in iron is 0.028 cm^2/g. The estimate of the effective thickness is complicated by photon trajectories that are not radial and by photons that scatter into or out of the chamber and/or produce secondary electrons in the chamber.) So the expected calibration factor is approximately 15.6*0.9 = 14.0 R/h•Ci, which is in good agreement with the measured value of 13.9 R/h•Ci.

COMPARISON WITH TLDS

I calculated the average NEWNET dose rate for a complete year (September or October 2000 to September or October 2001), omitting major anomalies; (one 15 microR/h glitch per day contributes a 1% error, so occasional glitches are not significant). Then I multiplied by 24 and by 365.25 to calculate mR/y and adjusted by the ratio of the individual PIC calibration to the average calibration (from the table above) to get the "Adjusted NEWNET" data (mR/y).

I divided the TLD data by 0.973 to convert mrem to mR. (Note: according to our procedures and Table 4, page 63, of NCRP 69, the correct factor should have been 0.96; however, the MAQ TLDs were calibrated by ESH-4 in mR/h and the results were actually multiplied by 0.973 to convert to mrem/h, i.e., dividing by 0.973 restores the original TLD calibration.)

The following table compares NEWNET with the TLDs.

Station	raw NEWNET (μR/h)	Adjusted NEWNET (mR/y)	TLD (mR/y)	Ratio
Espanola	13.0	109	112	1.03
Santa Clara	15.9	141	146	1.04
San Ildefonso	13.4	114	119	1.04
Met tower	16.9	151	152	1.01
East Gate	16.4	143	147	1.03

The TLD data are 3% higher than the NEWNET data. This surprisingly good agreement results from a combination of factors, some favoring TLDs and others favoring NEWNET. Both the TLDs and the NEWNET PICs are calibrated with Cs-137 but they respond differently to lower energy gammas. The PICs have a higher response near 100 keV because Ar has a higher atomic number than LiF. The PICs have a lower response below 70 keV because they have 1/8 inch steel walls. And the TLD-100 chips

contain natural lithium, which causes a slight response to cosmic-ray neutrons. In conclusion, the agreement is better than I expected.

CONCLUSION

The calibration factor is **13.9 R/h•Ci** for a type-D Cs-137 source in its 0.5-inch-thick box with the black sponge pad between the source and the PIC.